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Effects of Soil Salinity Status on Pineapple II. Chemical Composition

H. Wambiji, S. A. El-Swaify, and D. P. Bartholomew

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FOREWORD

Departmental Paper 25, Hawaii Agricultural Experiment Station, Contribution 646, Hawaii Institute of Geophysics, is a continuation of Departmental Paper 22 and Contribution 612, respectively. Both are based on a thesis submitted by the senior author in partial fulfillment of the requirements for the M.S. degree, University of Hawaii.

ABSTRACT

Effects of soil salinity on the Na, Ca, Mg, K, and Cl content of pineapple slips and 8- and 12-month-old transplants were determined. The plants were grown for 6 months in pots in a greenhouse. Soil salinity levels corresponded to electrical conductivities of 2, 4, 6, and 8 mmhos/cm in saturated soil solution and were adjusted by use of NaCl. It was found that Na and Cl uptake generally increased with increasing salinity level and duration of treatment. However, as expected due to ionic competition, all other measured elements generally declined under both level and duration.

These findings indicate that effects of salinity on pineapple as reported in Part I (Departmental Paper No. 22) are due not only to osmotic factors but also to nutritional imbalances. Possible problems due to stresses of transplanting and lack of favorable greenhouse environment are elaborated.

EFFECTS OF SOIL SALINITY STATUS ON PINEAPPLE
II. CHEMICAL COMPOSITION

H. Wambiji, S. A. El-Swaify, and D. P. Bartholomew

INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr], long known for its resistance to water stress, was also shown by a short-term greenhouse study to be relatively tolerant to soil salinity when grown on a well-structured soil (Wambiji and El-Swaify, 1974). Physical measurements as reported in the above study, though valuable in assessing salt effects on growth, shed little light on the mechanisms responsible for a crop's tolerance, or sensitivity, to salt effects. Changes in the chemical composition of plants provide a useful index for indicating possible plant nutritional imbalances, specific ion effects, osmotic adjustments, and/or changes in quality of tissue due to the presence of salt in soil or in irrigation water (Bernstein, 1964). Little such information is available for tropical crops in general (Syed and El-Swaify, 1973) and for pineapple in particular. This study was conducted to evaluate the effects of different soil salinity levels on the chemical composition of pineapple plants throughout the growth period reported in Part I.

MATERIALS AND METHODS

The surface plow layer of Wahiawa silty clay, a Tropeptic Eutrustox (previously classified as a Low Humic Latosol) and an important soil for growing pineapple in Hawaii, was used as a planting medium in greenhouse pots. Other characteristics of this soil were reported earlier (Wambiji and El-Swaify, 1974). Plants were potted from slips and from 8- and 12-month-old transplants. Nutritional requirements were maintained by foliar sprays except for P, which was applied as a basal dressing as superphosphate in granular form at the rate of 200 kg/ha. Foliar sprays for N, K, and Mg consisted of 200 ml of each from solutions containing 2.5%, 2.0% and 0.5% NH_4NO_3, K_2SO_4, and $MgSO_4$, respectively. B (as H_3BO_3), Mn (as $MnSO_4 \cdot 4H_2O$), Cu (as $CuSO_4 \cdot 5H_2O$), Zn (as $ZnSO_4 \cdot 7H_2O$), and Mo (as $[NH_4]_2MoO_4$) were supplied at 50 ml of the foliar spray containing 2.86, 1.81, 0.08, 0.22, and 0.5 mg of the respective salt at biweekly intervals. Fifty ml of a solution containing 50 mg of $FeSO_4$ were sprayed weekly on each plant. Sprays were applied at sunset to allow for better nutrient absorption and to avoid possible salt accumulation on leaves and subsequent salt burn resulting from daytime applications (Sanford, 1959).

Salinity treatments were begun 1 month after planting, whereby NaCl was used to provide salinity levels of control [2 (low), 4 (medium), 6(medium-high), and 8 (high) mmhos/cm]in saturated soil solution. Sudden shock by salt concentration gradients was avoided by increasing salinity levels gradually, at the rate of 2 mmhos/cm per 24 hours, until the final desired level was achieved. Periodic collection and analysis

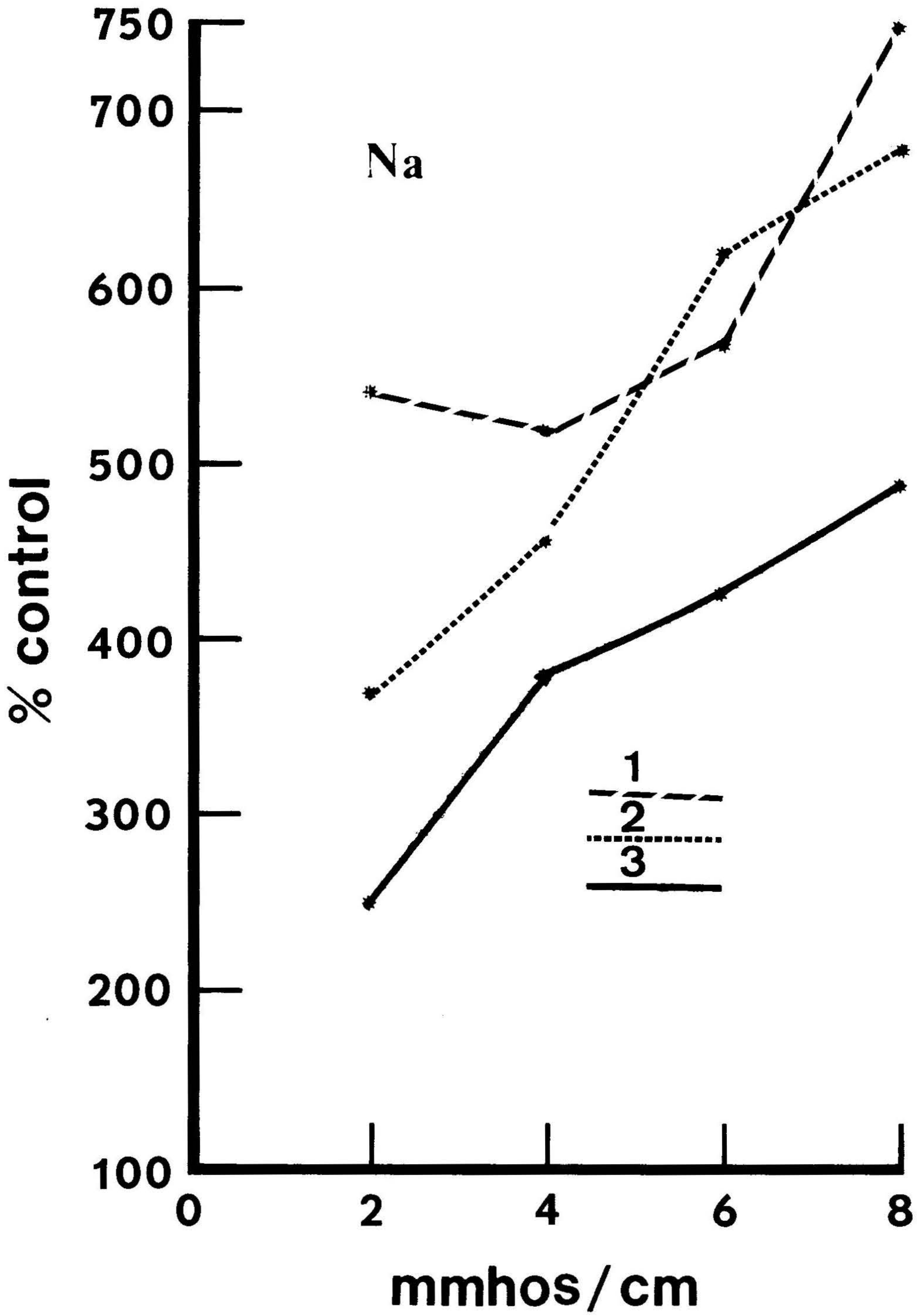

Figure 1. Effect of salinity treatment on the Na content of total plant tissue at the end of growth period for slips (1), 8-month-old transplants (2), and 12-month-old transplants (3).

Table 1. Effect of salinity treatment on Na content of D-leaves during growth period

Planting	Month	Control Na content,* %	Na content, % of control: Low	Medium	Medium-high	High
Slips	1	0.87	140	125	134	123
	2	1.20	123	123	114	104
	3	0.48	139	198	208	208
	4	0.23	243	296	370	470
	5	0.43	157	234	323	426
	6	0.77	174	208	205	239
8-month-old transplants	1	0.43	112	156	137	167
	2	0.46	113	157	146	222
	3	0.34	138	153	162	174
	4	0.57	211	215	191	236
	5	0.68	140	134	149	176
	6	0.16	575	638	750	900
12-month-old transplants	1	0.49	135	163	175	188
	2	0.42	162	210	219	246
	3	0.50	150	171	185	198
	4	0.68	151	159	165	157
	5	0.65	160	169	177	178
	6	0.54	204	207	204	233

*Actual percentages of element in plant tissue which are equivalent to 100%.

of soil samples showed that salt levels in soil solution considerably exceeded these intended levels in a manner which was reported earlier (Wambiji and El-Swaify, 1974). Other details of the experimental layout were also reported in that publication.

D-leaves, considered sufficiently expanded but also sufficiently active to be indicative of nutritional status, were harvested at 1-month intervals. The whole leaf was washed, chopped into small pieces, dried overnight at 70°C, then ground in a Wiley Laboratory Mill. At the end of the growth period the whole plant was composited and ground.

Chemical analyses were performed for Ca, Mg, K, and Na in extracts prepared by ashing 0.2 g of each sample, to which a few drops of 0.5 N HNO_3 were added, at 550°C, and the resulting material digested in 1 N HCl over a hot plate. All extracts were filtered to remove precipitated SiO_2 prior to chemical analysis. Chlorides were extracted from 0.2-g portions by 50 ml of 0.1 N HNO_3 as described by Gilliam (1970). Ca and Mg were determined by a Perkin Elmer atomic absorption spectrophotometer, Na and K by a Beckman DU flame-photometer, and Cl by use of a silver-silver chloride electrode on a Beckman Expandomatic pH meter.

RESULTS

Salinity Effects on Na Content

Table 1 shows the changes in Na content of D-leaves throughout the growth period. It is noted that both the length of treatment and the salinity level have pronounced effects on increasing Na content in leaves. F values from analysis of variance showed both effects to be significant at the 1% level. Figure 1 illustrates the effects of salinity level on the final Na content of composited plants at the end of the growth period. These data confirm the above-stated trend, which is in agreement with findings on other crops (Bernstein, 1964; Syed and El-Swaify, 1973; among others). This was particularly expected in this case because NaCl was used to adjust all salinity levels.

Salinity Effects on K Content

A competitive absorption between Na and K has usually been noted under conditions where Na was the prevailing element in soil or solution and appears to be confirmed in this study. Table 2 shows an apparent inverse relationship between salinity level and K content of D-leaves during the final 2 months of growth and of composited plants at the end of the growth period. However, this relationship holds best for D-leaves of 12-month-old transplants and for the composited final samples of the 8-month-old transplants. The large variations in K content are expected in view of the findings of Sideris and Young (1945), which showed a K gradient ranging from 200 to 400% in different parts of the pineapple plants. In contrast to Na, therefore, it would appear that K content is not an adequate index for salt effects on the nutritional status of the pineapple plant.

Table 2. Effect of salinity treatment on K content of D-leaves (at 5 and 6 months) and of composited plants (final)

Planting	Month	Control K content,* %	K content, % of control: Low	Medium	Medium-high	High
Slips	5	4.23	109	84	85	120
	6	4.55	73	65	80	96
	final	5.15	96	102	110	114
8-month-old transplants	5	4.03	81	84	79	92
	6	4.02	96	97	80	84
	final	4.53	93	80	80	64
12-month-old transplants	5	4.50	77	67	67	92
	6	4.21	85	73	77	66
	final	3.80	91	99	109	107

*Actual percentages of element in plant tissue which are equivalent to 100%.

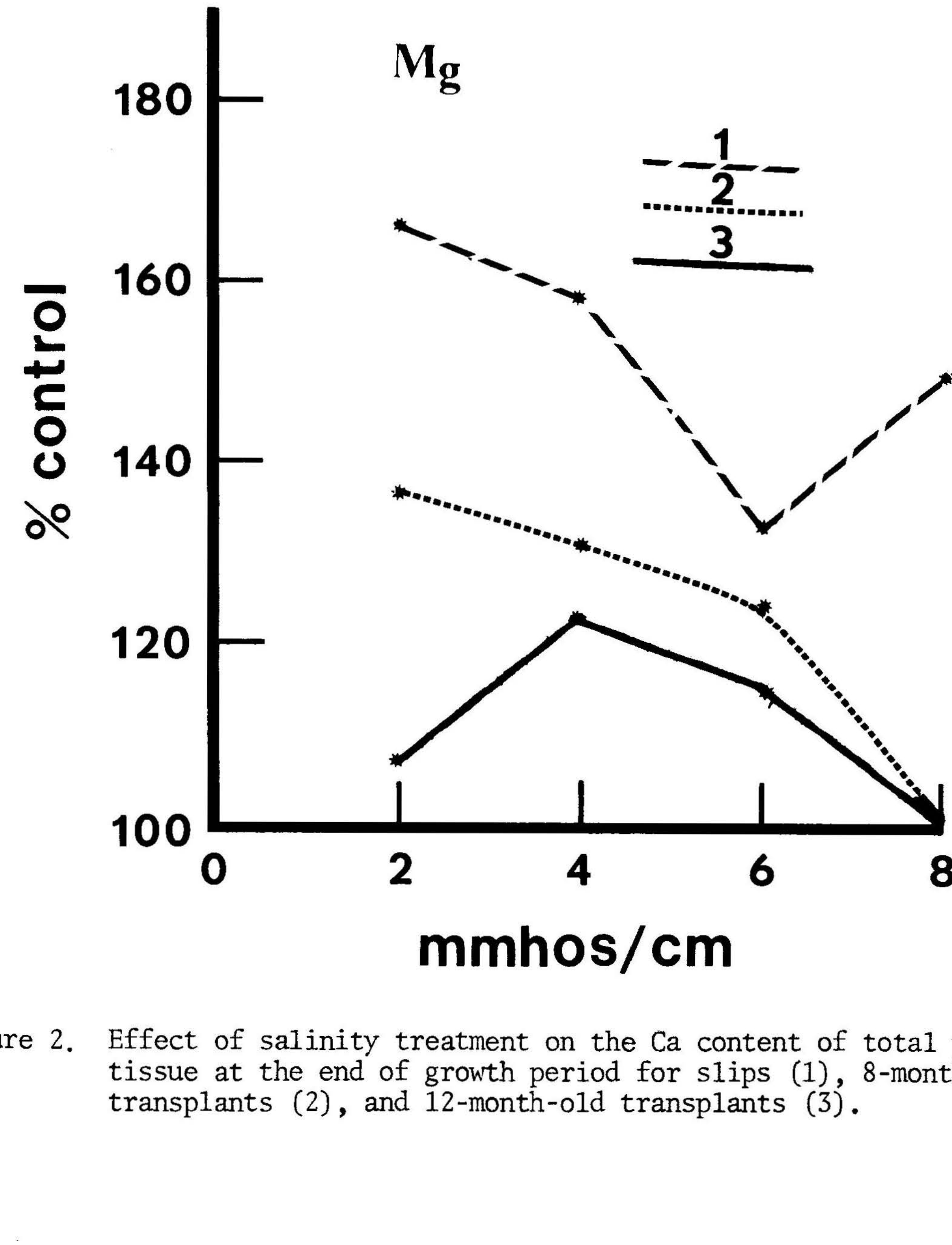

Figure 2. Effect of salinity treatment on the Ca content of total plant tissue at the end of growth period for slips (1), 8-month-old transplants (2), and 12-month-old transplants (3).

Table 3. Effect of salinity treatment on Ca content of D-leaves during growth period

Planting	Month	Control Ca content,* %	Ca content, % of control Low	Medium	Medium-high	High
Slips	1	0.22	105	107	96	78
	2	0.19	117	109	124	88
	3	0.23	106	109	100	118
	4	0.24	120	93	149	145
	5	0.30	72	88	83	96
	6	0.21	100	100	120	136
8-month-old transplants	1	0.43	79	74	88	107
	2	0.39	79	69	97	118
	3	0.37	116	73	105	92
	4	0.41	110	90	100	120
	5	0.35	117	103	103	109
	6	0.36	114	106	100	111
12-month-old transplants	1	0.42	93	86	93	76
	2	0.28	118	100	100	89
	3	0.31	103	110	100	135
	4	0.33	115	115	82	103
	5	0.39	97	90	72	82
	6	0.30	97	93	100	93

*Actual percentages of element in plant tissue which are equivalent to 100%.

Salinity Effects on Ca Content

Table 3 shows the effects of salinity on the Ca content of D-leaves throughout the growth period. The effect of salinity level on Ca uptake by slips was found to be insignificant as indicated by F values obtained from analysis of variance. Furthermore, the Duncan Multiple Range test indicated no significant effect for the duration of treatment on Ca uptake by the slips. Analysis of composited plants at the end of the growth period revealed, as shown in Figure 2, that Ca content for the treated slips as a whole was higher than that in controls, but indicated no significant change due to salinity treatment. On the other hand, the 8-month-old transplants reflected a steady increase with increased soil salinity, reaching a maximum of 140% of control at the highest level. However, the 12-month-old transplants exhibited erratic trends which culminated in a decline in Ca content at the highest salinity treatment to a level almost equal to that of control. Comparison between the three age groups confirms that the 8-month-old transplants provide a better index of pineapple's response to salinity, perhaps due to the fact that the plant displays its most vigorous growth at this stage. Higher Ca content in the composited plants than in the D-leaves was more generally noted, an observation easily explained by the finding of Sideris and Young (1945) that more Ca accumulated in the stems than in any other part of the pineapple plant.

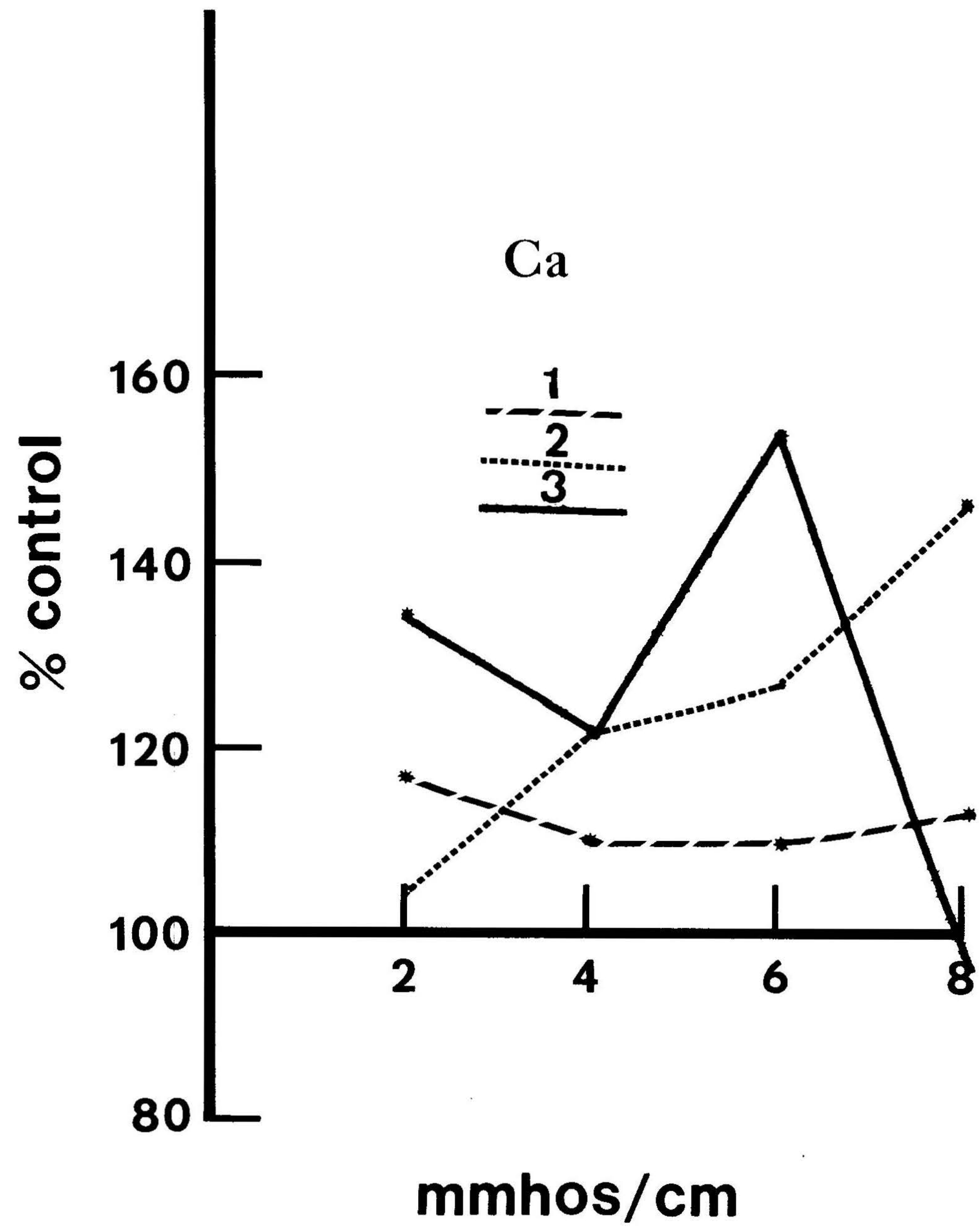

Figure 3. Effect of salinity treatment on the Mg content of total plant tissue at the end of growth period for slips (1), 8-month-old transplants (2), and 12-month-old transplants (3).

Table 4. Effect of salinity treatment on Mg content of D-leaves during growth period

Planting	Month	Control Mg content,* %	Mg content, % of control: Low	Medium	Medium-high	High
Slips	1	0.18	106	100	94	78
	2	0.12	141	117	142	92
	3	0.16	125	95	88	88
	4	0.19	111	84	84	137
	5	0.17	118	94	84	100
	6	0.21	86	100	129	114
8-month-old transplants	1	0.28	96	86	93	82
	2	0.26	85	85	104	92
	3	0.21	119	67	95	62
	4	0.25	96	84	76	68
	5	0.23	91	91	65	57
	6	0.21	105	100	81	76
12-month-old transplants	1	0.30	87	93	90	70
	2	0.22	64	86	73	64
	3	0.19	153	100	105	153
	4	0.25	96	84	72	69
	5	0.29	72	66	63	59
	6	0.21	86	71	95	86

*Actual percentages of element in plant tissue which are equivalent to 100%.

Salinity Effects on Mg Content

Table 4 shows that Mg content of slips was affected equally by salinity levels and by duration of treatment. F values for analysis of variance were significant at the 1% level only for time effect. For transplanted plants, neither factor had a significant F value at any level. Figure 3 shows that clearer trends were observed for Mg content of composited plants than reported above for D-leaves. In confirmation of trends observed for Ca, the 8-month-old transplants exhibited a steady decline in Mg content with salinity treatment, thus providing the best index among the three age groups for cation-adsorption in the presence of abundant Na supply. Mg content of slips declined with increasing soil salinity until a level of 6 mmhos/cm was reached; beyond this, Mg level increased. For the 12-month-old transplants, an increase in Mg content was observed with soil salinity up to a level of 4 mmhos/cm; beyond this, Mg content declined gradually until the maximum salinity level was reached. In no case, however, did Mg levels fall below those for control treatments.

Table 5. Effect of salinity treatment on Cl content of D-leaves during growth period

Planting	Month	Control Cl content,* %	Cl content, % of control Low	Medium	Medium-high	High
Slips	1	0.58	271	305	243	245
	2	0.28	279	429	582	746
	3	0.69	146	230	303	331
	4	1.38	122	202	217	258
	5	1.68	163	294	226	292
	6	1.96	140	164	263	298
8-month-old transplants	1	0.91	192	175	223	274
	2	1.63	134	145	142	167
	3	1.41	167	190	201	236
	4	0.68	178	216	238	297
	5	0.48	217	329	450	652
	6	0.60	220	280	353	430
12-month-old transplants	1	0.54	302	302	294	330
	2	1.45	145	189	203	204
	3	0.96	207	159	240	308
	4	0.94	176	140	150	178
	5	0.95	116	121	154	180
	6	0.76	129	116	95	90

*Actual percentages of element in plant tissue which are equivalent to 100%.

Salinity Effects on Cl Content

Table 5 shows Cl content of D-leaves throughout the growth period. Increasing soil salinity levels caused higher Cl uptake by plants for all stages of growth. The table also shows that the duration of treatment effected a change in Cl uptake. The F values from the analysis of variance showed Cl uptake to be significantly affected by both of the above variables at the 1% level. Again, the change in content for the 8-month-old plants appears more reflective of salinity effects. Nevertheless, Cl did not seem to provide a consistent index of salinity effects, even when NaCl was the main source of salinity in soil. This is in contrast to work reported elsewhere for other crops (e.g., Syed and El-Swaify, 1973) showing a definite continuing increase in Cl content with increasing Cl in soil solution.

DISCUSSION

Whereas it was generally noted that ion competition played only a small role, the absorption of Ca and Mg by pineapple plants exhibited a slight decline with increasing soil salinity. The depression of Ca and Mg uptake was most significant at the medium-high to high salinity levels. Decline in K uptake was consistent under all treatments while absorption of the prevailing anion underwent a general increase.

These observations are generally in accord with those of Gerson and Poole (1971), who noted that influx of competing cations was inhibited and influx of complementary ions increased with increasing external salt concentrations. It may be pointed out, however, that the apparent erratic trends in some nutrient contents are probably due to lack of complete protection from rainfall in the greenhouse used for this study. This resulted in salt movement and leaching from growth pots in a manner that was presented earlier (Wambiji and El-Swaify, 1974). Trends observed for Cl uptake were most illustrative of this problem. It is of interest to note that severe leaf-burn observed in many crops because of Cl uptake and accumulation was not confirmed in this study. However, Sideris and Young (1954) indicated the possibility of metabolic disorders in the plant as a result of Cl accumulations. Since no other anions were determined, it is difficult to speculate whether prevailing Cl depressed the uptake of any other anions.

Evaluation of the performance of the pineapple plant on the basis of D-leaf analysis has also proved to be a problem. This is because the technique does not take into account the fact that these leaves are no longer produced by the plant after floral initiation. This was allowed to occur naturally (not chemically induced) and was noted in only four of the 12-month-old transplants during the second month of growth. The earliest floral initiation was observed for the low salinity level followed 1 week later by the medium and high levels, then 2 weeks later by the control. Soon after the appearance of the flowers, the leaves dropped and withered, then small fruits developed, which ripened very prematurely.

CONCLUSIONS AND INTERRELATIONSHIPS WITH PART I

Significant trends in growth and nutrient composition of pineapple plants with increasing age and salinity have been reported here and by Wambiji and El-Swaify (1974). However, in most cases, growth rates of control plants were quite low. Freshly harvested slips can range in weight from 75 to greater than 150 g. Where slips cultured with nutrient solution were grown in growth chambers, plant fresh weights at 6 months of age were greater than 600 g with d-leaf weights of 60 to 80 cm even under less-than-optimum temperatures (D. Bartholomew, 1974*). The observed growth for the 12-month transplants reported in Part I (Wambiji and El-Swaify, 1974) may be accounted for by utilization of stored carbohydrates (Sideris and Krauss, 1955). Although reasons for the unusually low growth rates in the two other age groups are not known, stomatal closure and cessation of photosynthesis have been reported to occur in some plants when leaf water potential drops to values in the range of -7 to -16 bars (Hsiao, 1973). Such levels were measured in control plants in this experiment. Neales et al. (1968) reported that photosynthesis declined to near zero when *Agave americana* (a plant which has crassulacean acid metabolism as demonstrated by massive dark fixation of CO_2 into malic acid, as does pineapple) was subjected to water stress for 1 day. Later data by Neales (1972) and Connelly (1972) for pineapple show that a decline in photosynthesis resulted in a greater CO_2

* Personal communication

fixation in the dark, but a large decline in total CO_2 fixed.

The relatively low moisture contents in the range of 84 to 85% for the slips and 12-month transplant-control plants also support the hypothesis that these two groups of plants were subjected to some sort of environmental stress. A lack of adequate environmental control in the greenhouse was stated as a possible reason for this problem. On the other hand, whole plant moisture contents for the 8-month transplant-control plants were 93.3%. The reason for such unusually high values may again be attributed to an unfavorable greenhouse environment. Above optimum night temperatures for growth do result in high plant moisture contents (D. Bartholomew, 1974*). Abnormal root development after transplanting and/or physiological drought resulting from inadequate aeration could result in water stressed plants in soils where water content was at or above field capacity. Water stress in older plants could result from the lack of adequate new root development necessary to supply the existing large leaf area and to compensate for damage to the root system due to transplanting. The inability of flowering pineapple plants to initiate new root development has been documented (Sideris and Krauss, 1955).

It may be generally stated that the effects on pineapple reported in both parts of this study were due to osmotic factors contributed by the presence of added salt, to imbalances due to changes in uptake of nutrients, and also to stresses encountered by the transplanted plants grown under relatively difficult greenhouse conditions. Insofar as control treatments in each age group have experienced the latter factors only, the effects of salinity treatments may be looked upon as relative effects compared to those of the untreated plants.

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*Personal communication

LITERATURE CITED

Bernstein, L. 1964. Effects of salinity on mineral composition and growth of plants. Plant Analysis and Fertilizer Problems IV, pp. 25-45.

Connelly, P. R. 1972. The effects of thermoperiod on the carbon dioxide uptake and compensation point of the pineapple plant, *Ananas comosus* (L.) Merr. Ph.D. dissertation, University of Hawaii.

Gerson, D. F., and R. J. Poole. 1971. Anion absorption by plants. Plant Physiol. 48:509-511.

Gilliam, J. W. 1970. Rapid measurement of chlorine in plant materials. Soil Sci. Soc. Amer. Proc. 35:512-514.

Hsiao, T. C. 1973. Plant responses to water stress. Ann. Rev. Plant Physiol. 24:519-570.

Neales, T. F. 1972. Effect of night temperature on the assimilation of carbon dioxide by mature pineapple plants, *Ananas comosus* (L.) Merr. Aust. J. Biol. Sci. 26:539-546.

Neales, T. F., A. A. Patterson, and V. J. Hartney. 1968. Physiological adaptation to drought in the carbon assimilation and water loss of xerophytes. Nature 219:469-472.

Sanford, W. G. 1959. Review of research on nutrient foliar sprays 1916-1959. Unpublished Report, Pineapple Research Institute, Hawaii.

Sideris, C. P., and B. H. Krauss. 1955. Transpiration and translocation phenomena in pineapples. Amer. J. Bot. 42:707-709.

Sideris, C. P., and H. Y. Young. 1945. Effects of different amounts of potassium on growth and ash constituents of *Ananas comosus* (L.) Merr. Plant Physiol. 20:609-630.

Sideris, C. P., and H. Y. Young. 1954. Effects of chlorides on the metabolism of pineapple plants. Amer. Jour. Bot. 4:847-854.

Syed, M. M., and S. A. El-Swaify. 1973. Effect of saline water irrigation on N. Co. 310 and H50-7209 cultivars of sugarcane. II. Chemical composition of plants. Trop. Agr. (Trinidad) 50:45-51.

Wambiji, H., and S. A. El-Swaify. 1974. Effects of soil salinity status on pineapple. I. Growth parameters. Dep. Paper 22. Hawaii Agr. Exp. Sta. 14 pp.

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